SINGLE PILOT SCANNING BEHAVIOR IN SIMULATED INSTRUMENT FLIGHT

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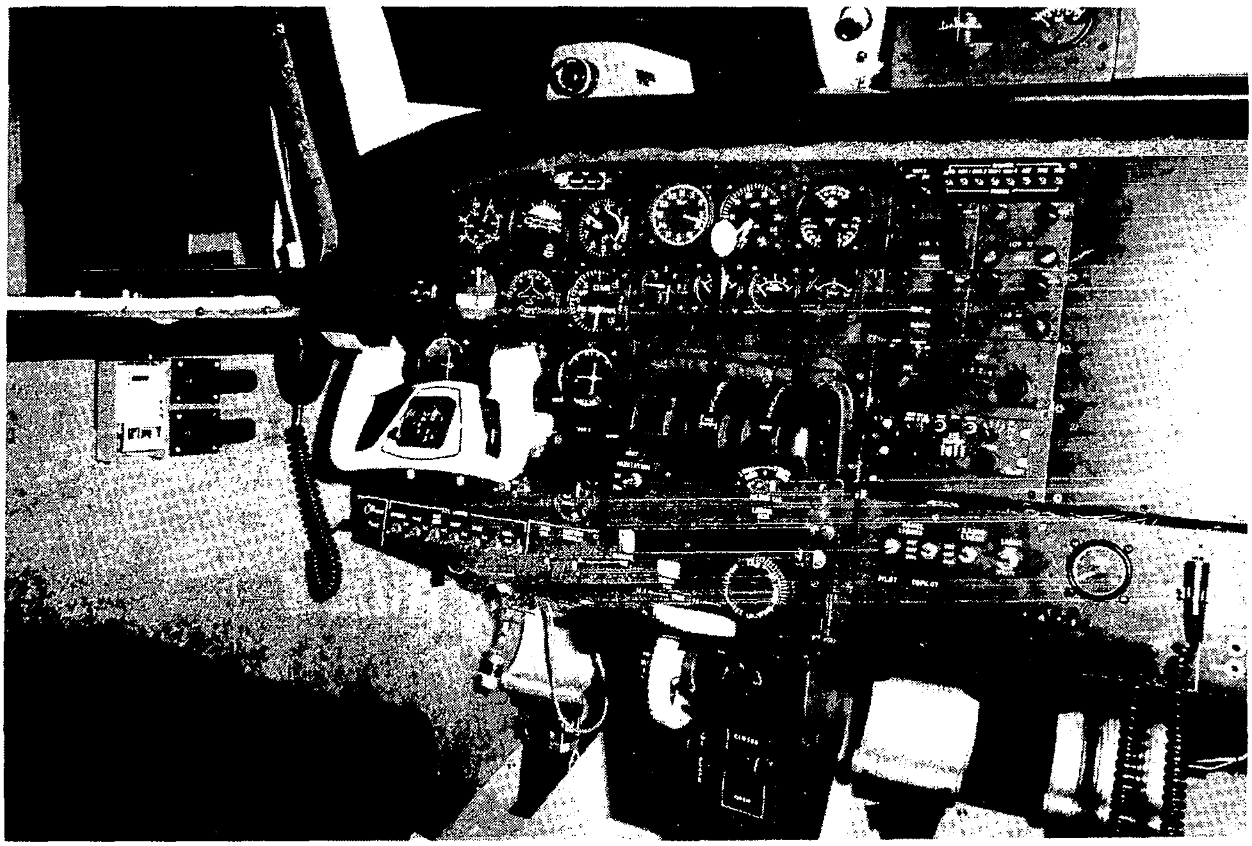
ABSTRACT

A major objective of research in avionics and controls is to reduce the pilot's workload and provide needed information in an optimal manner. This paper presents results from a simulation of general aviation instrument flight tasks in which the pilot's scan pattern and lookpoint were measured along with control inputs and state variables. The objective of the study was to provide a baseline for comparing results from later studies of advanced avionics. Some of scanning parameters measured are described, and conclusions from this and subsequent studies are presented.

This photograph shows the instrument panel in the simulator. The TV camera was mounted above the instrument panel. Shown to the right of the camera is an acoustic sensor which monitored the level of cockpit noise. The IR source and collection point for the oculometer was a small two-axis mirror assembly mounted to the left of the panel.



Three instrument-rated pilots flew the nine flight maneuvers shown below, with three replications. The tasks were chosen to represent those which might occur during parts of a flight, and which taken together could represent a flight profile. Task 9, an ILS approach, was divided into seven consecutive phases for analysis. Pilots flew all tasks manually and made callouts at the beginning of each phase.

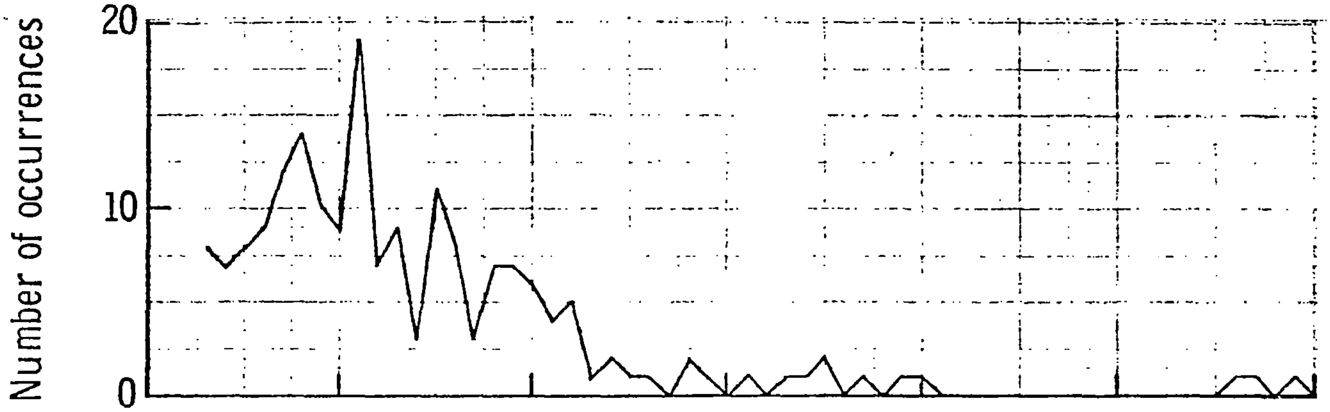
SIMULATED FLIGHT TASKS

RUN	DESCRIPTION
1.	STRAIGHT & LEVEL (1 MINUTE)
2.	CLIMB
3.	CLIMBING TURN
4.	LEVEL TURN
5.	DESCENT
6.	DESCENDING TURN
7.	INTERCEPT AND TRACK VOR
8.	HOLDING PATTERN
9.	INTERCEPT AND TRACK LOCALIZER INTERCEPT & ESTABLISH G.S. TO MM

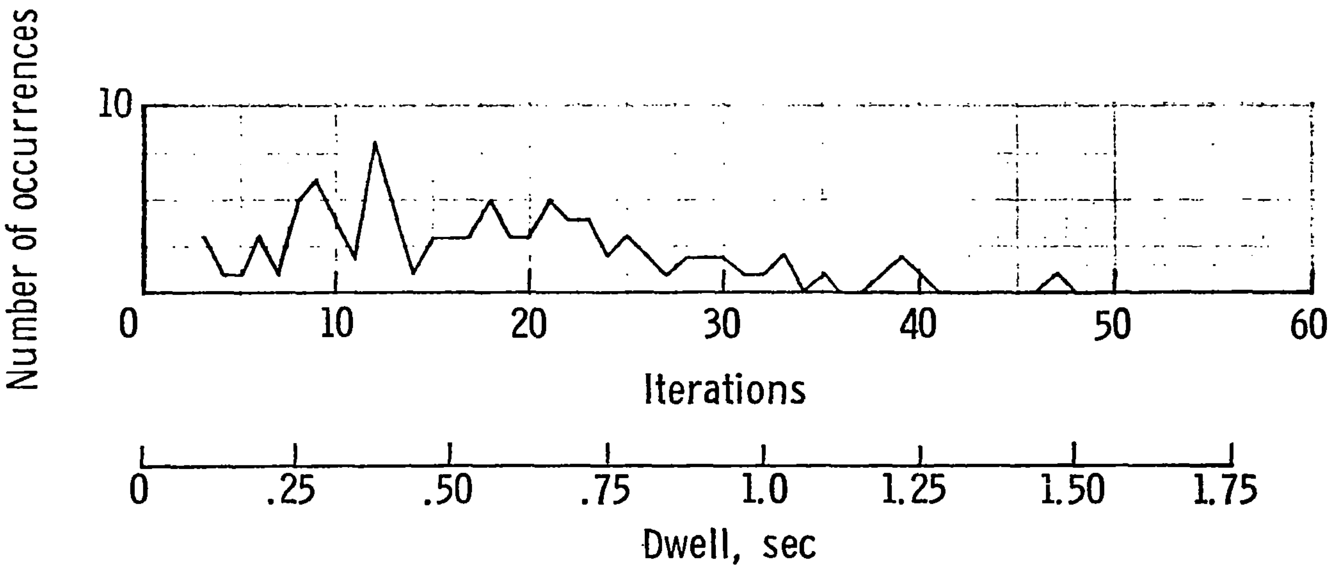
The dwell (fixation) time on each instrument and transitions between instruments were determined. This table shows the percent time on instruments for each of the simulated tasks. A dash signifies that no fixation occurred; a zero indicates that the percent of time on instrument was less than .05 percent.

Cockpit Instrument	Run Number (see previous page) 1	2	3	4	5	6	7	8	9
Tachometer	-	-	-	-	-	-	-	-	-
ADF	0	0.1	0.2	0.1	0.1	0	0	0	0.2
Marker Bcn.	0	0	-	2.4	0	0	0.1	0.1	0
Altimeter	10.6	9.4	4.1	6.7	9.2	3.9	8.1	6.1	3.2
Artificial Horizon	58.7	64.3	59.7	62.7	67.0	61.5	63.3	56.5	42.4
Airspeed	1.3	2.8	2.9	1.5	2.9	5.1	1.5	1.7	1.2
IVSI	1.7	2.8	1.3	0.4	2.1	2.5	1.9	1.6	1.2
Dir. Gyro.	25.4	19.7	17.6	11.9	17.9	13.7	18.9	18.9	31.7
Turn & Bank	0.9	0.8	14.0	14.3	0.6	12.8	0.8	4.3	0.5
VOR 1	0.1	0	-	0	0.1	0.3	4.9	4.6	17.0
DME	1.0	0.1	0	0	0.1	-	0.4	0.7	1.1
VOR 2	0.1	0	0.2	0.1	0	-	0.2	5.5	0
Window	-	0	-	-	-	-	-	0	1.6

The data analysis method only counted fixations of three iterations (.1 sec) or longer. This figure shows the distribution of dwell (fixation) time occurrences for the artificial horizon and VOR instrument in the final phases of the simulated approach. Most of the dwell times are .2 - .4 seconds. The artificial horizon, VOR indicator and directional gyro accounted for over 90% of the pilot's visual attention in this task.

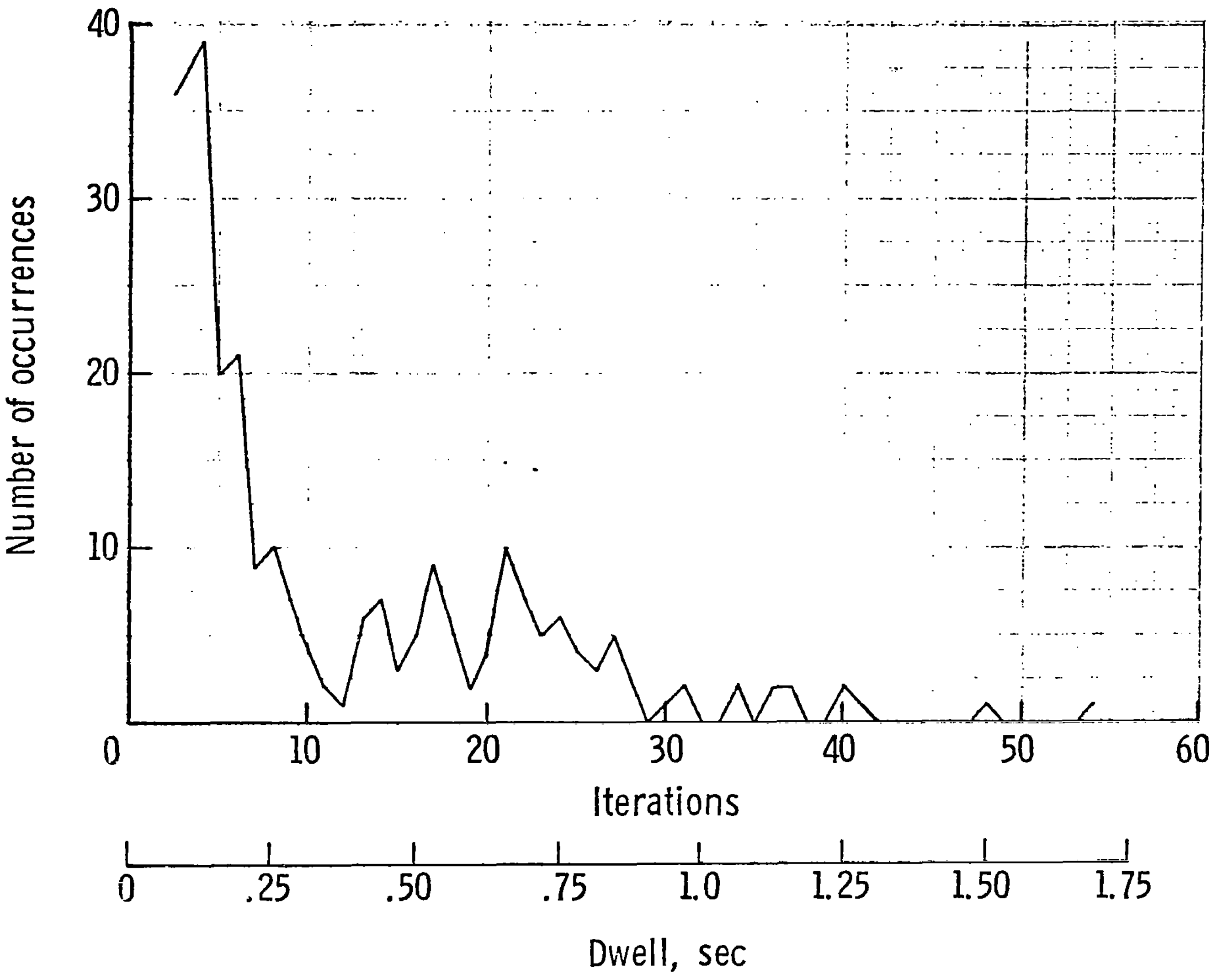


(a) Artificial horizon

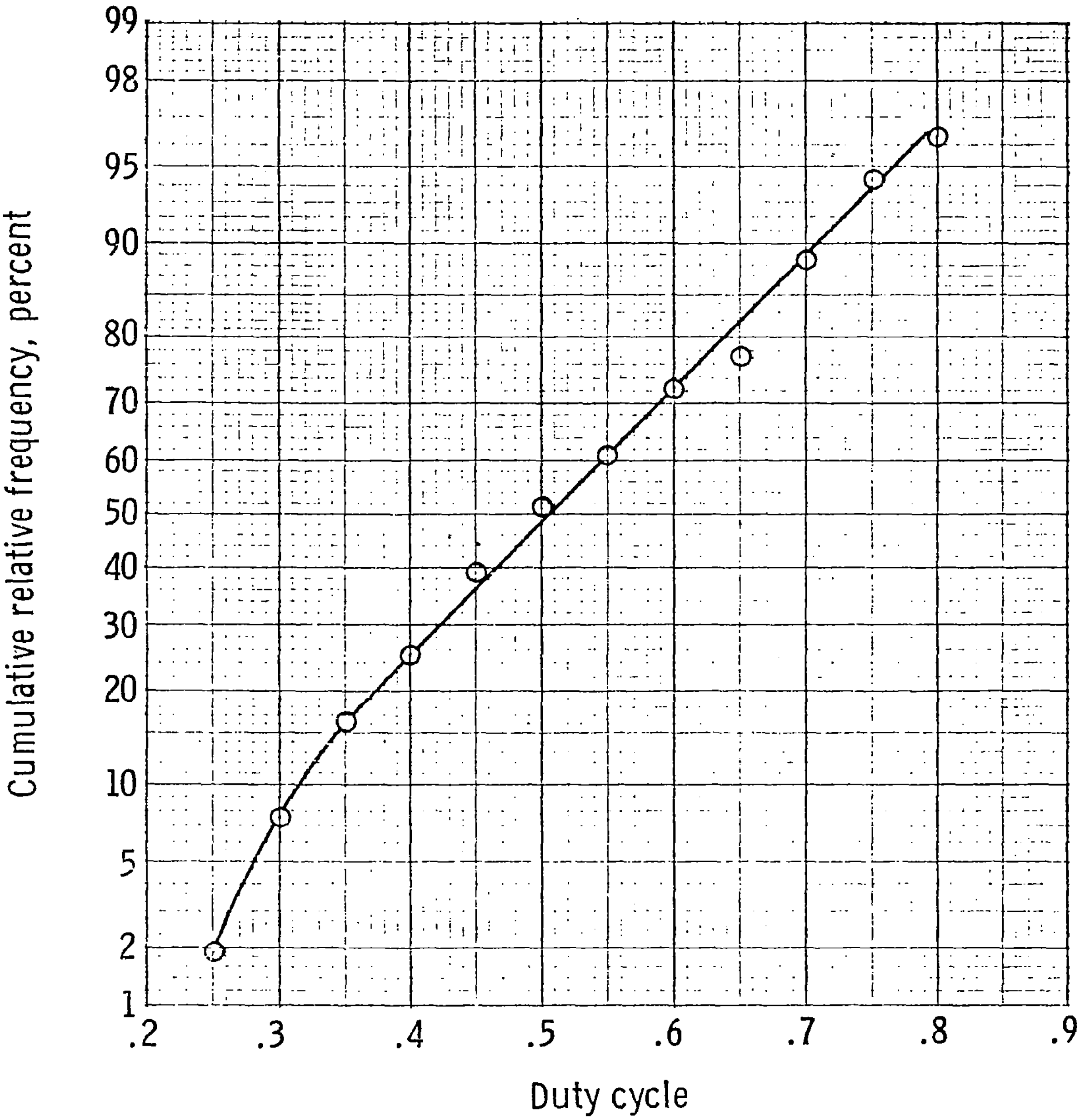


(b) VOR 1

This figure shows the dwell time data for the directional gyro. The large number of very short dwell times (less than .25 sec) may have occurred because the instrument was located directly in front of the pilot, at the center of his scan pattern. The amount of information obtained in such short fixations is uncertain. A second mode appears to occur in the data at .5 - .8 seconds dwell time. This may be more indicative of the time required to assimilate the displayed data.

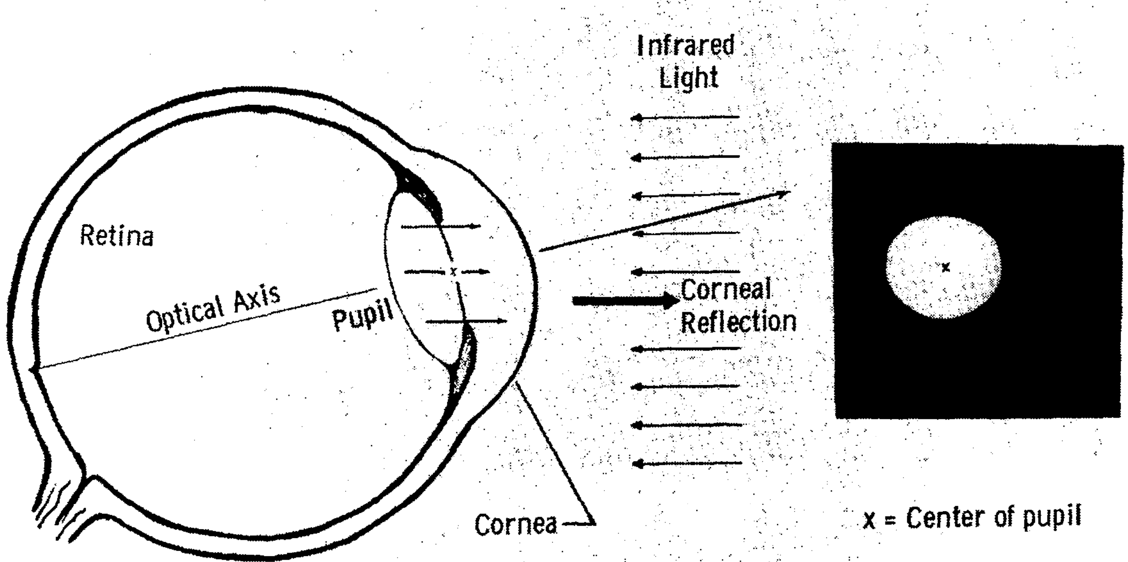


Another parameter investigated was duty cycle, defined as the dwell time divided by the sum of dwell time plus the time spent looking at other instruments before returning. The duty cycle data for the directional gyro in task 9 was found to resemble a normal distribution when fixations of less than .3 seconds were omitted. The cumulative frequency distribution for the directional gyro data, shown plotted on probability paper, confirms that the data appears to be normally distributed over much of its range. However, chi-square tests of duty cycle data for the artificial horizon and the VOR indicator were not consistent between pilots or tasks.



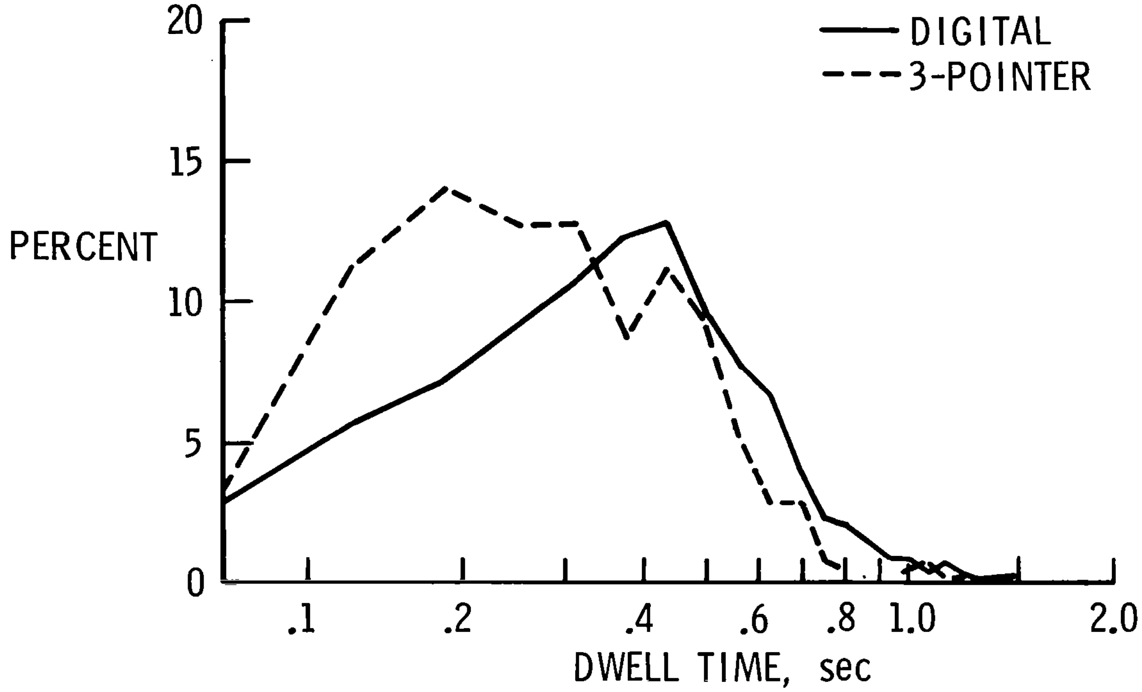
An oculometer was used to determine the pilot's lookpoint. This figure illustrates the basic sensing principle. The oculometer uses a low power infrared source to illuminate the pilot's eye. The high reflectivity of the retina causes an infrared-sensitive TV camera to see a backlighted pupil plus a small bright corneal reflection. A microcomputer processes the TV signal in real time to compute the angle of rotation of the eyeball with respect to the IR beam and the coordinates of the lookpoint on the instrument panel.

BASIC SENSING PRINCIPLE



The value of visual scanning data in investigating display requirements is illustrated in this figure. In a subsequent study, Harris and Spady (ref. 1, 2) replaced the three-needle altimeter with an altimeter having only a digital readout, and monitored the visual scanning behavior in a landing approach task. This figure shows the dwell time histograms for the two altimeters. The high percentage of short dwell times suggests that the analog altimeter provided the desired information in a more quickly assimilated form.

ALTIMETER MONITORING DWELL HISTOGRAM



This figure summarizes general findings on scanning behavior based on use of the oculometer in both GA and commercial transport studies. Scanning behavior is one tool in understanding the information needed by the pilot and determining how to present the information efficiently.

GENERAL FINDINGS OF SCANNING BEHAVIOR

- o SCANNING IS A SUBCONSCIOUS CONDITIONED ACTIVITY
    - o PILOTS DON'T KNOW HOW THEY SCAN
    - o CONSCIOUS THOUGHT DISRUPTS SCANNING BEHAVIOR
- o THE CONDITIONED ACTIVITY OF SCANNING IS
    - o DIFFERENT FOR EACH PILOT
    - o AFFECTED BY THE PILOT'S ROLE
    - o SENSITIVE TO THE DESIGN OF INSTRUMENTS
    - o AFFECTED BY DISPLAY-CONTROL SYSTEM COMPATABILITY
    - o MODIFIED WITH EXPERIENCE AND BETTER UNDERSTANDING

REFERENCES

1. Harris, Randall L., Sr.; and Christhilf, David M.: What Do Pilots See in Displays? Presented at the Annual Meeting of the Human Factors Society, Los Angeles, CA, October 13-17, 1980.

2. Spady, Amos A., Jr.; and Harris, Randall L., Sr.: How a Pilot Looks at Altitude. NASA Technical Memorandum 81967, April 1981.